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A study of techno-economic feasibility analysis of solar photovoltaic (PV) power generation in the province of Adana in Turkey

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Abstract

In this study, the examination of techno-economic feasibility analysis of a solar photovoltaic (PV) power generation were carried out by taken into account a PV power plant that has the capacity of 100 kW_e as an example, in the province of Adana, Turkey. For this purpose, the technical characteristics of the PV array, the amount of electricity production, the cost of electricity production, investment and operating costs, payback periods and the amount of CO_2 emissions reduction were determined for the solar PV plant. By using the total area of 653.4 m^2 PV cell, total 135,403 MWh of electricity was produced in the power plant. To this end, total 5 units of PV arrays were required with the surface area of 130.7 m^2 each. In this case, the system efficiency was determined as 12.2%, the annual specific efficiency of the system was 1,352 kWh/kW and the amount of CO_2 emissions reduction was obtained as 119,830 Mg/year. The payback period of the system was 7.8 years and the electricity production cost was 0.1400 TL (Turkish Liras)/kWh, respectively.

Keywords: Solar PV energy, Techno-economic feasibility analysis, Solar power generation, Turkey

1. INTRODUCTION

The use of eco-friendly renewable energy sources has become widespread in recent years due to decrease of fossil fuel reserves and the increase of their damage to the environment. The solar energy-related scientific studies has increased and renewable

energy technologies have been determined according to the results of these studies in many developed and developing countries because of the European Commission's target for 2020 is to raise the share of total energy consumption throughout Europe produced from renewable resources to 20%. As in Europe, Turkey also plans to reduce fossil fuel consumption and aims to increase the usage of renewable energy. Intensive researches are being done about the efficient and economical utilization of solar energy all over the world, as well as in Turkey (Ashhab *et al*., 2013; Pavlović *et al*., 2013; Zhang and He, 2013; Verhees *et al*., 2013; Kaygusuz, 2004; Demirbas, 2006; Khodayar *et al*., 2008; Comakli *et al*., 2008; Balat, 2005; Kirtay, 2010; Mathew *et al*., 2013; Adaramola *et al*., 2012; Balat, 2004).

Turkey is more fortunate than many other countries due to its geographical location for solar energy potential. According to the General Directorate of Electrical Power Resources Survey and Development Administration (EIE, 2014), the annual average total insolation duration is identified as 2640 h (7.2 h/day) and the annual average solar radiation is identified as 1311 kWh/m^2-year (3.6k Wh/m^2-day) in Turkey. The South Eastern Anatolia Region is the sunniest region of Turkey, and the Mediterranean region is in the second rank.

In order to produce hot water, solar collectors are used to convert solar energy into heat energy, in the regions of Mediterranean and Aegean Coast, in Turkey. Currently, the amount of installed solar collectors is about 12 million square meters; the annual production capacity is 750 thousand square meters in Turkey. Also, some part of this production is exported. Annual production of solar thermal energy is around 420 thousand TOE. In this state, Turkey is a remarkable solar collector manufacturer and the user in the world.

When there is no electricity grid or being away from residential areas; solar cells can be used to meet the energy needs, because they are economically feasible. For this reason, they can be installed to meet rural electricity needs or for the purpose of signaling. In Turkey, solar cells are used in public organizations like Forestry Lookout Tower, Turkish Telecom, lighthouses and highway lighting, General Directorate of Electrical Power Resources Survey and Development Administration, Muğla University, Ege University, to meet small power needs and research purposes and the photovoltaic installed capacity has reached the level of 1 MW.

To reduce Turkey's energy dependence on foreign sources, which is in the rate of 73%, the share of electricity production from renewable energy sources is targeted to be at least 30% in the country by the year 2023. For this purposes energy production from domestic sources plans to increase, as fossil fuel usages planning to decrease. At the same time the protection of ecological balance will be carried out by reducing greenhouse gas emissions by the year 2023. In this concepts, electricity production from solar energy will be widespread and both theoretical and practical information be developed, qualified and competent persons will be trained and employed for this sectors. In this regard, the country's progress and development is expected to speed up.

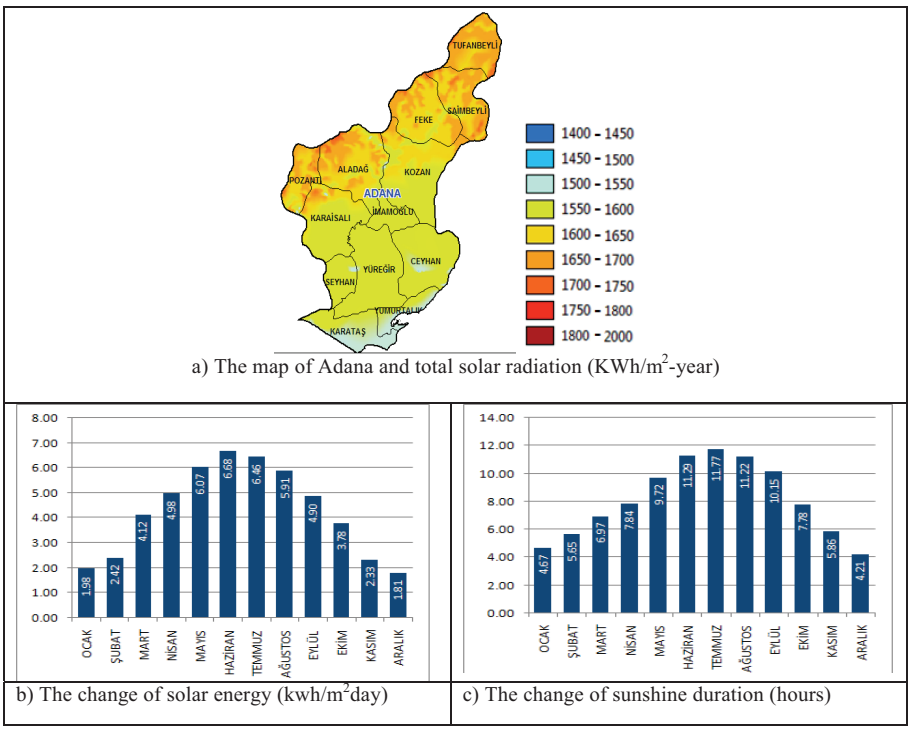
In this study, the examination of techno-economic feasibility analysis of a solar photovoltaic (PV) power generation were realized by taken into account a PV power plant that has the capacity of 100 kWe as an example in the province of Adana in Turkey. For this purpose, the technical characteristics of the PV array that used in PV

plants, the amount of electricity production, the cost of electricity production, investment and operating costs, payback periods and the amount of reduction in CO_2 emissions were all defined for this solar PV plant.

2. MATERIAL AND METHODS

2.1. Solar energy potential

The province of Adana has the properties of Mediterranean climate. While summers are hot and dry, winters are mild and rainy. The numbers of summer days of Adana are 195.6 days in a year. 134.4 of these days are defined as tropical days. The elevated areas of Adana have the higher level of solar energy amount compared to the areas that have lower height (Fig. 1a). The total solar energy of Adana is in the range between 1.81 and 6.68 kwh/m^{2}day (Fig. 1b) and the insolation duration is in the range between 4.21 and 11.77 hours (Fig. 1c).



a) The map of Adana and total solar radiation (KWh/m^2-year)

b) The change of solar energy (kwh/m^{2}day)

c) The change of sunshine duration (hours)

Figure 1. The change of annual solar energy and sunshine duration in Adana (DMI, Turkish State Meteorological Service, 1975-2013).

2.2. Techno-economic Analysis of Photovoltaic Power Plant

In this section, the techno-economic analysis of electricity production in a grid-connected solar PV power plant with the capacity of 100 kW_e is described.

2.2.1. The surface srea of the photovoltaic array

The insolation duration of the PV array that designed for the PV power plants can be defined based on the solar radiations that reach to the array in one day, at the optimum angle;

$$t = \frac{\phi \times E_s}{1000\ \mathrm{W/m^2}} \tag{1}$$

Where;

t = The insolation (sunshine) duration of the panel (h)
φ = Optimum angle (°)
E_s = Solar radiation energy (Wh/m^2)

The maximum power that can be obtained from the photovoltaic array can be determined by depending on the highest current and the battery voltage that produced of the array at the temperature of 25 °C. This can be expressed as:

$$P_{PV} = I_{P(\max)} \times V_B \tag{2}$$

Where;

P_{PV} = Maximum power amount that can be obtained from the array (W)
$I_{P(max)}$ = Maximum current amount that produced by the array (A)
V_B = The voltage value of the battery (V)

The energy amount that can be obtained from photovoltaic array on a daily basis depends on insolation duration of the array and the maximum available power;

$$E_{PV} = P_{PV} \times t \tag{3}$$

Where;

E_{PV} = The amount of electricity that can be gained from the array (Wh)

The amount of energy that can be obtained from a photovoltaic array reduces depending on the efficiency of the equipment in the PV system is;

$$\eta_e = \eta_i \times \eta_{ccd} \times \eta_B \times \eta_{ca} \tag{4}$$

Where;

η_e = The efficiency of the equipment

η_i = The efficiency of the inverter
η_{ccd} = The efficiency charging control device
η_B = The efficiency of the battery
η_{ca} = The efficiency of the cable

The efficiency of the photovoltaic array varies depending on the temperature of the cell. Catalog data relating to the efficiency of photovoltaic cells are determined based on measured values at a constant temperature of 25 ˚C in laboratory conditions. Therefore, in case of a change of the outside temperature, the efficiency of the PV array also changes. During the experiments that carried out in laboratory, the temperature of a PV cell is called as the nominal operating temperature of a PV cell (T_{PVn}). It is accepted that the temperature of the array is 22 ˚C higher than outdoor temperature. In the different the ambient temperatures, the operating temperature of photovoltaic array can be calculated with equation (5). While the voltage of photovoltaic array increases due to the increase of the array's temperature, the current of photovoltaic array decreases due to the increase of the array's temperature. The changes with the temperature difference of the voltage and current values that can be obtained from the photovoltaic array are given in the following equations (Ozturk and Kaya, 2013);

$$T_P = T_a + (T_{PVn} + 25) = T_a + 22 \tag{5}$$

$$V_{ocv2} = V_{ocv} - \Delta T \times 0.0842 \tag{6}$$

$$I_{scc2} = I_{scc} - \Delta T \times 0.0086 \tag{7}$$

Where;

T_P = Panel temperature (˚C)
T_a = The ambient temperature (˚C)
T_{PVn} = Nominal operating temperature of PV cells (˚C)
V_{ocv} = Open-circuit voltage (V)
I_{scc} = Short circuit current (A)

The efficiency of photovoltaic array ($\eta_{PVarray}$) can be determined by following equation:

$$\eta_{PVarray} = \frac{V_{ocv2} \times I_{scc2}}{V_{ocv} \times I_{scc}} \tag{8}$$

The photovoltaic arrays are placed at the optimum angle, but the solar radiation comes on the array from different angles during the day, therefore photovoltaic efficiency of the system decreases. The change of angle is 15° when photovoltaic arrays are placed at the optimum angle. The decrease of the efficiency is taken as 5% for the angle change of 15° difference. The total efficiency of the photovoltaic system

is determined as follows (Ozturk and Kaya, 2013):

$$\eta_{te} = \eta_{ea} \times \eta_P \times \eta_e \tag{9}$$

Where;

η_{te} = Total efficiency of PV system
η_{ea} = The efficiency of the angle inclination

When determining required number of PV modules, the maximum amount of energy must be taken into account. To meet the energy requirements in such systems, the required number of solar PV modules can be calculated as follows (Ozturk and Kaya, 2013);

$$n_{PV} = \frac{E_r}{E_{PV} \times \eta_{te}} \tag{10}$$

Where;

n_{PV} = The number of solar PV modules
E_r = The amount of required energy (Wh)
E_{PV} = The amount of electricity that can be gained from the PV array (Wh)

Photovoltaic arrays are very sensitive to shading. Therefore, it should be paid much importance not to be in the shade during the installation of PV arrays. The solar module (or panel) is comprised of a number of photovoltaic cells connected in series with a metallic material to get usable voltage. If the power of a PV cell falls because of shading, other cells will be forced to fall to the same degree of the power with this PV cell. In other words, there is no difference being shaded between a half of a cell and a half of a PV module. The soiling of the PV array is similar to the shading effect, which causes the losses, around the level of 3%.

To get the highest levels of solar radiation for PV arrays during a year, they must be placed in the right direction, which in the tilt of the angle that equal to the latitude of the area by inclining to the south. Generally, to optimize the performance of PV panels in the winter, they must be tilted up from horizontal at an angle 15° greater than the latitude. In an opposite manner, if a PV system is going to be used in summer, the most advantageous way to optimize the performance of the PV panels for summer, the PV panels must be tilted 15° less than the latitude.

2.2.2. Charge controller

A PV charge controller is a device that provides the interface between the PV array and a battery. Solar PV charge controllers (also known as solar charge regulators) are used in solar PV energy systems to protect the battery from being overcharged and over-discharged. Either condition will damage a lead acid battery. The minimum continuous current value of the charge control device which is required for Photovoltaic systems is calculated as follows (Ozturk and Kaya, 2013);

$$\frac{I_{mp} \times s_{PV} \times 1.25}{2} \leq I_{ccd} \tag{11}$$

Where;

I_{mp} = the current in the maximum power (A)
I_{ccd} = The current of charge control device (A)

2.2.3. Photovoltaic system inverters

A solar inverter (a PV inverter) is added to the PV system to convert the variable direct current (DC) output of a photovoltaic (PV) solar panel into a utility frequency alternating current (AC) that can be fed into a electrical grid or used by a local, off-grid electrical network. Thus, the DC voltage is converted into 220 V and 50 Hz sine wave.

A solar inverter is an essential part of any grid-connected PV plant, which is an environmentally power generation system that uses the photovoltaic effect to convert sunlight into electrical power. The main duty of an inverter is to convert direct current into alternating current. This conversion is necessary because PV modules generate direct current from sunlight while public power distribution grids use alternating current for many reasons. In Turkey, inverters are used that converted alternating current to 220 V AC at the 50 Hz of frequency. Inverters can function with little loss of energy; the devices can achieve 85-95% efficiency. Two types of inverters are widely used in the market.

Inverter waveforms:

(1) Square wave: An alternating current wave-form that switches between positive and negative values every half period. Their efficiency and cost is low per unit power.
(2) Sine wave: They are suitable for grid connected systems. Their cost is high per unit power.

A converter that used in PV system must meet the maximum amount of power need. The number of inverter units that will be used in a PV system can be calculated according to the following equation:

$$n_i = \frac{P_{r_{\max}}}{P_{i_{\max}}} \tag{12}$$

Where;

n_i = The number of required converter units (units)
$P_{r\ max}$ = The required amount of maximum power (W)
$P_{i\ max}$ = The highest power of inverter (W)

Inverters are expensive elements of PV systems. They also require different safety equipments. Owing to the fact that high amount of current passes through the inverter-battery cable, the thickness of the cable should be selected as 5-10 cm. Also a blocking diode and a fuse should be placed into the terminal of DC input side and output of the

inverter. System can be connected in parallel with measuring devices that measure current and voltage. Similarly, various electronic circuits can be added to the system depending on the type of the application. There are also power tracking devices in some systems that used for the purpose of maximizing the PV system's output power. They are also continuously tracking the maximum power point (MPP) of the system, which is necessary for the system.

2.3. Economic analysis of photovoltaic systems

The economic evaluation criteria of the project are mathematical techniques that used for the comparison of the costs and benefits of the projects in regard to commercial, economic and/or social aspects. There are many criteria that developed for the acceptance of a single project or multiple separate projects. They are also used as prioritization criteria in order to selecting and ranking of the project. The most commonly used ones are:

(1) Net present value (NPV)
(2) Internal rate of return (IRR)
(3) Benefit/cost ratio
(4) Payback period

2.3.1. Payback period

Payback period is the required length of time or the number of years for the obtainment of the net inflow of money in order to meet or exceed to the amount of an investment cost. In other words, the length of time that required to recover the cost of an investment. In this method, the payback period of a given project is an important determinant of whether to undertake the project or not. That is, the attractiveness of investment projects depends on the payback periods. The shorter payback period increases the desirability of the project, as the longer payback period decreases the desirability of the project. To calculate payback period of a project depends on whether the cash flow per period from the project is even or uneven. In case they are even, the formula to calculate payback period is calculated as follows;

$$\text{The payback period} = \text{Investment cost of the project/Annual net inflow of money} \quad (13)$$

2.3.2. Net present value (NPV)

Net Present Value (NPV) is the most widely used method in the analysis of investment projects. Net Present Value is the difference between net cash inflow that will be provided during the economic life of a project's and investment expenses that discounted to present value with a certain amount of reduction that previously accepted. To accept a project according to this method the net present value should be greater than or equal to zero ($NPV \geq 0$). In the selection of alternative projects, the net present value of the project that has the highest value is given the priority (on condition that being greater than or equal to zero). Net Present Value, NPV, and the

Future Value can be determined by the following equations;

$$PV = \frac{C_n}{\left(1+r\right)^n} \tag{14}$$

$$\text{NPV} = C_0 + PV = C_0 + \frac{C_n}{\left(1+r\right)^n} \tag{15}$$

$$FV = C_0\left(1+r\right)^n \tag{16}$$

Where;

PV = Present Value
C_n = Cash flow will take place after n period
r = The discount (interest) rate
n = The number of periods
NPV = Net Present Value (NPV)
C_0 = The initial cash flow
FV = The Future Value

The initial cash flow (C_0), in equation (15) and (16) is usually equal to the initial investment cost and it has a negative value.

$$NPV = \left[\sum_{t=0}^{n} \frac{B_t}{\left(1+r\right)^t}\right] - \sum_{t=0}^{n} \frac{C_t}{\left(1+r\right)^t} \tag{17}$$

Where;

$C_{t\,in}$ = The cash inflows of t year
$C_{t\,out}$ = The cash outflows of t year

In case of a positive result of the assessment (NPV > 0), the investment project is accepted, otherwise (NPV < 0) is rejected. If NPV = 0, that means the annual cash flow is only enough to meet the annual operating cost and the investment costs.

3. RESULTS AND DISCUSSION

The results are determined by a mathematical model calculation. The actual yields of the photovoltaic system can deviate from these values due to fluctuations in the weather, the efficiency of modules and inverters and other factors. The system diagram of the 100 kW_e PV plant is given in Figure 2, which can not represent and cannot replace a full technical drawing of the solar system.

Climate data records belong to Adana-İncirlik AFB were used to simulate the PV system in mathematical model calculations. The general specifications of the 100 kW_e PV system are given in Table 1.

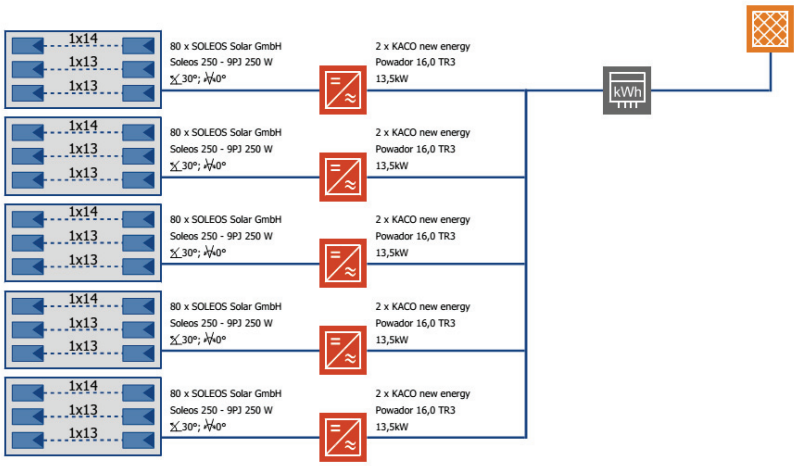


Figure 2. The arrangement of the 100 kWe PV system.

Table 1. The general specifications of the 100 kWe PV system

Location:	Adana/İncirlik AFB		
Climate Data Record:	Adana/İncirlik AFB (1886-2005)		
PV Output:	100 kWp		
Gross/Active PV Surface Area:	653.4 m^2/653.4 m^2		
PV Array Irradiation:	1,107,125		
Energy Produced by PV Array (AC)	135,403 kWh		
Grid Feed-in	135,403 kWh		
System Efficiency	12.2%		
Performance Ratio:	79.8%		
Specific Annual Yield:	1,352 kWh/kWp		
CO_2 Emission Avoided:	119,830kg/a		
System in Grid Connected Operation			
Location:	Adana/İncirlik AFB	PV Output:	100.00kWp
Climate Data Record	Adana/İncirlik AFB	Gross/Active PV Surface Area:	653.4 m^2/653.4 m^2
Number of Arrays	5		
Array 1:1			
Output:	20.00 kW	Ground Reflection	20.0%
Gross/Active PV Surface Area:	130.7 m2/130.7m2	Output Losses due to…	
PV Module	80×	Deviation from AM 1.5:	1.0%
Manufacturer:	SOLEOS Solar GmbH	Deviations from Manufacturer's Specification:	2.0%
Model:	Soleos 250-9PJ	In Diodes:	0.5%
Nominal Output:	250 W	Due to Soiling	0.0%
Power Rating Deviation:	0%	**Inverter**	2×
Efficiency (STC):	15.3%	Manufacturer:	KAKO New Energy
No. of Modules in Series	14|13|13	Model:	Powador 16.0 TR3
MPP Voltage (STC):	423|393|393 V	Output:	13.50 kW
Orientation:	0.0°	European Efficiency	95.6%
Inclination:	30.0°	No. of MPP Trackers:	3
Mount:	With Ventilation	MPP Tracking:	200 V to 510 V
Shade:	No		

In the region of Adana, Turkey, 135,403 MWh of electricity can be produced by using PV cells with a total area of 653.4 m^2 at the PV power plant with the capacity of 100 kW_e. For this purpose, total 5 units PV arrays were required with the surface area of 130.7 m^2 each, which were directed towards the south at the angle of 30°. Each array comprised of total 30 PV modules that connected in series with three rows in the design of 14-13-13. Each array had inverters, the power and the efficiency of the inverters was 13.5 kW and 95.6% per each, respectively. In this case, the system efficiency was 12.2%, the annual specific yield was 1,352 kWh/kW and CO_2 emissions reduction was in the level of 119,830 Mg/year.

The simulation results of the 100 kWe PV system are given in Table 2. In the case of the array efficiency was 12.9% and the inverter efficiency was 94.6%, the amount of power that generated can be explained according to the solar energy that came to the surface of a PV array which was 221,425 MWh and the electrical energy amount which generated from this solar energy was 28582 MWh DC or 27,081 MWh AC. In this case, the total of 5 PV arrays that got solar energy to their surfaces in the amount of 1,107,125 MWh from sun and therefore, the efficiency of the system was 12.2% and 135,403 MWh AC power was produced. The simulation results of 100 kW_e PV system can be seen in Table 2.

Table 2. The simulation results of 100 kWe PV system.

Simulation Results for Total System			
Irradiation onto Horizontal:	1,001,728 kWh	Own Use:	155.2 kWh
PV Array Irradiation:	1,107,125 kWh	Energy Produced by PV Array:	142,908 kWh
Irradiation minus Reflection:	1,060,595 kWh	System Efficiency:	12.2%
Energy from Inverter (AC)	135,403 kWh	Performance Ratio:	79.8 %
Consumption Requirement:	0 kWh	Final Yield:	3.7 h/d
Energy from Grid:	155 kWh	Specific Annual Yield:	1,352 kWh/kWp
Results for Array 1:1			
Irradiation onto Horizontal:	200,346 kWh	System Efficiency:	12.2%
Array Irradiation:	221,425 kWh	Performance Ratio:	79.8 %
Energy Produced (AC):	27,081 kWh	Specific Annual Yield:	1,352 kWh/kWp
Own Use:	31 kWh	Array Efficiency	12.9%
Energy Produced (DC):	28,582 kWh	Inverter Efficiency	94.6%

The monthly changes of total 135,403 MWh AC power that will be produced at the power plant with the installed PV capacity of 100 kW_e are given in Figure 3. During the year, the amount of electricity that is to be produced in December is the lowest level of energy with the value of 7.5 MWh. On the other hand, the highest level is reached in July which has the value of 13.5 MWh.

The calculations results of financial analysis of the 100 kW_e PV system are given in Table 3. As it can be seen in the table the investment cost of the 100 kW_e PV plant was

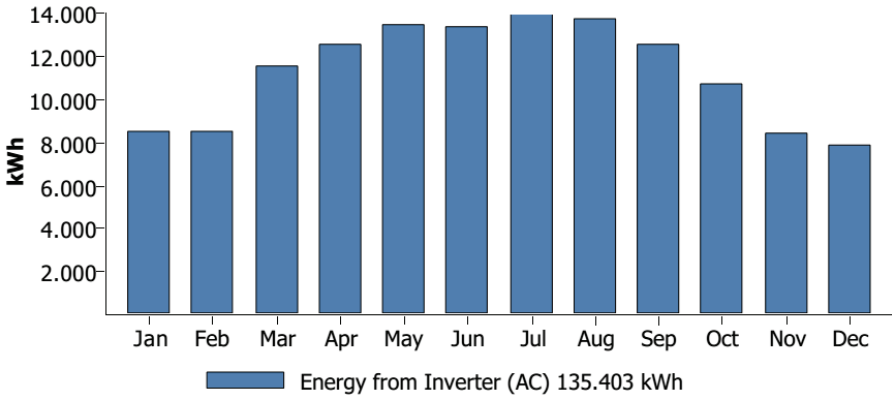


Figure 3. The monthly change of electricity production at the power plant with 100 kWe of installed PV capacity.

Table 3. The calculations results of financial analysis of the 100 kW PV system.

Financial Analysis Calculation	
System Data	
PV Output: 100.00 kWp	
System Operating Start: 01.11.2013	Total Degradation:10.00%
Electricity Feed-in	
Grid Concept:	Fuel Feed-in
For the First 20 Years:	0.3600 TL/kWh
Thereafter:	0.3600 TL/kWh
Basic Financial Analysis Parameters	
Assessment Period:	20 Years
Interest on Capital:	0.00%
All entries without sales tax	
Income and Expenditure	
Investments:	337,500.00
Operating Costs:	2,362.50 TL/a
Feed-in Payment Received in First Year:	48,745.21 TL/a
Tax	
Tax Rate:	18.0%
Depreciation Period	10 Years
Type of Depreciation Rate:	Linear Depreciation
Depreciation Rate	10.00%
Results According to Net Present Value Method	
Net Present Value:	448,313.22 TL
Payback Period:	7.8 Years
Yield:	9.3%
Electricity Production Cost:	0.14 TL/kWh

337,500 TL (Turkish Liras) and with annual operating cost of 2,362.5 TL (Turkish Liras), total 48,725.21 TL (Turkish Liras) worth of electricity was sold for the first year. The net present value of the 100 kW_e PV system was 443,313.22 TL (Turkish

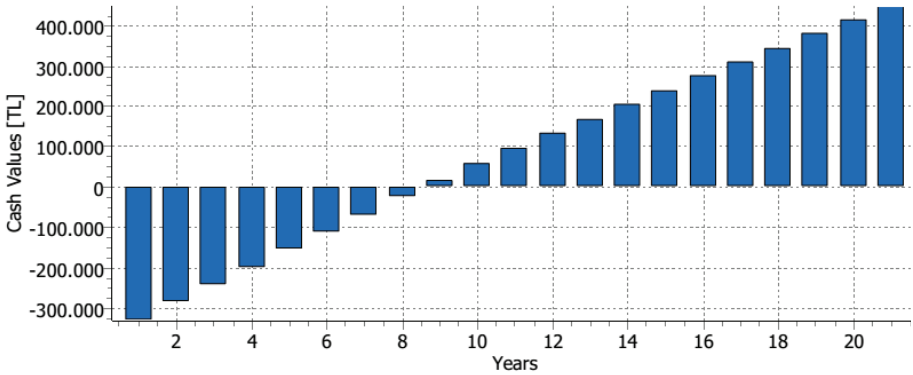


Figure 4. The yearly change of cash flow values of the 100 kWe PV power plant.

Liras) in the case of system life is 20 years, the depreciation period was 10 year, depreciation ratio was 10% and the selling price of electricity was 0.3600 TL (Turkish Liras)/kWh, the payback period was 7.8 years, the cost of electricity production was 0.1400 TL/kWh, respectively. Accordingly, with 12.2% of system efficiency, total 135,403 MWh AC power could be produced from 1,107.125 MWh solar energy that has come to the surface of total 5 PV arrays.

The yearly change of cumulative cash flow values of the 100 kW_e PV power plant are given in Figure 4. As it can be seen from the figure, while cash flow values are in negative values for the first year, they increase to the positive values from the end of system's payback period which is 7.8 years. The cumulative cash flow passes over the value of 400 000 TL (Turkish Liras) at the end of 20 years.

The yearly change of the incomes that obtained by the sales of electricity from the 100 kW_e PV power plant to the national grid can be seen in Figure 5 and the change of operating expenses of the system during the economic life of 20-year period is

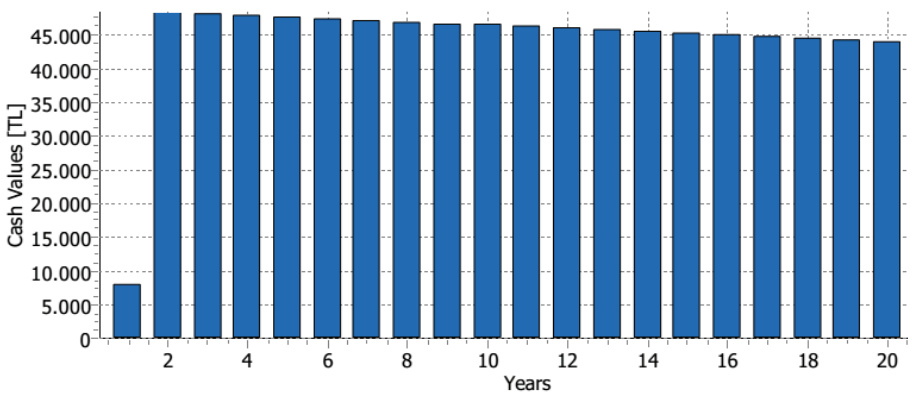


Figure 5. The yearly change of the incomes that will be obtained by sales of electricity from the 100 kWe PV power plant.

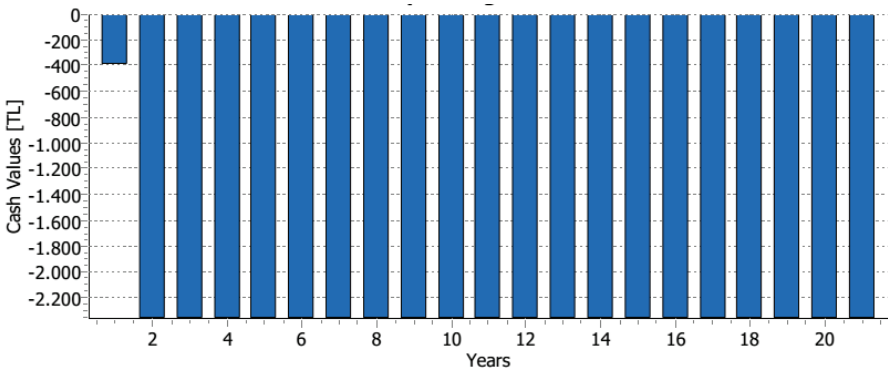


Figure 6. The yearly change of the operational expenses for the 100 kWe PV power plant.

given in Figure 6, respectively. The amount of income that obtained from the sale of electricity to the national grid which was generated in the PV power plant, with the annual operating cost was 2,362.5 TL (Fig. 6), reduces depending on the degradation rate (Fig. 5), which takes place in the PV plant.

The changes of before and after tax cash flow during the economic life of the system in the 100 kWe PV power plant are given in Figures 7 and 8, respectively.

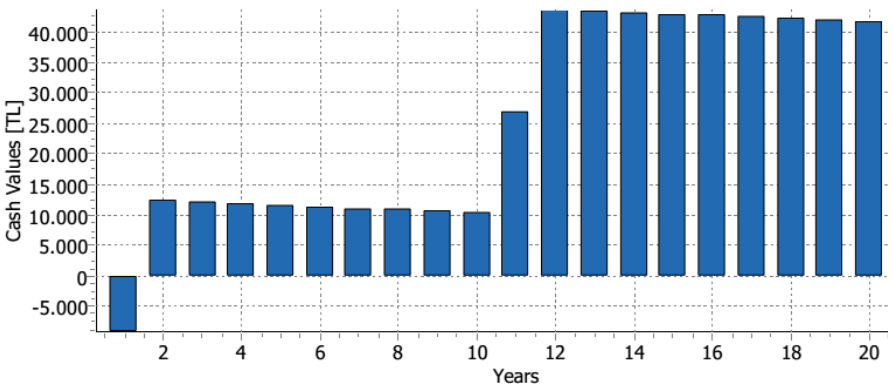


Figure 7. The yearly change of before tax cash flow for the 100 kWe PV power plant.

4. CONCLUSIONS

In this paper, the examination of a techno-economic feasibility analysis of a solar photovoltaic (PV) power generation was realized by taken into account a 100 kW_e PV power plant in Adana, Turkey. The cost of electricity production was calculated as 0.14 TL/kWh in the 100 kW_e PV power plant. The production cost of electricity reduces and the energy savings will be provided in the case of electricity generation from solar energy. As a significant result of the energy savings, fossil fuel consumption will be

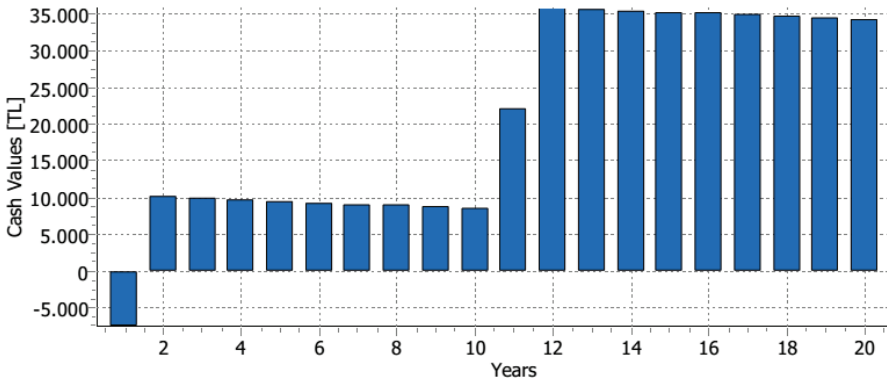


Figure 8. The yearly change of after tax cash flow for the 100 kWe PV power plant.

reduced for electricity generation. Therefore CO_2 gas emission will be reduced significantly. As it can be well known CO_2 (carbon dioxide) is the primary greenhouse gas which contributes to climate change. The burning of fossil fuels releases large amounts of carbon to the atmosphere, causing CO_2 concentrations in the atmosphere to rise. The amount of CO_2 emission reduction of the considered PV systems was calculated as 119,830 kg/year.

Thus, with the developments in electricity generation from solar energy there are many successful acquisitions are to be realized such as the reduction of electricity production cost, the contribution to the economy of the country, protection of the human health and the environment.

NOMENCLATURE

C_0	The initial cash flow
C_n	Cash flow will take place after n period
$C_{t\ in}$	The cash inflows of t year
$C_{t\ out}$	The cash outflows of t year
E_s	Solar radiation energy (Wh/m^2)
E_{PV}	The amount of electricity that can be gained from the array (Wh)
E_r	The amount of required energy (Wh)
FV	The future value
I_{scc}	Short circuit current (A)
I_{mp}	The current at the maximum power (A)
$I_{P(max)}$	Maximum current amount that produced by the array (A)
I_{ccd}	The current of charge control device (A)
n	The number of period (years)
NPV	Net Present Value
PV	Present Value
$P_{i\ max}$	The highest power of inverter (W)
P_{PV}	The maximum power amount that can be obtained from the array (W)
$P_{r\ max}$	The required amount of maximum power (W)

r	The discount (interest) rate
n_{PV}	The number of solar PV modules
n_i	The number of required inverter units (units)
n_{PV}	The number of solar PV (Photovoltaic) modules
t	The insolation duration (h)
V_{ocv}	Open-circuit voltage (V)
V_B	The voltage value of the battery (V)
(T_{PVn})	The nominal operating temperature of a PV cell
ΔT	Temperature difference (˚C)
T_P	Panel temperature (˚C)
T_a	The ambient temperature (˚C)
φ	Optimum angle (°)
η_e	The efficiency of the equipment
η_i	The efficiency of the inverter
η_{ccd}	The efficiency charging control device
η_B	The efficiency of battery
η_{ca}	The efficiency of cable
η_{te}	Total efficiency of PV system
η_{ea}	The efficiency of the angle inclination
$\eta_{PVarray}$	The efficiency of PV array
η_P	The efficiency of the panel

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